# Three-Channel Linear LED Driver with Analog and PWM Dimming

## DESCRIPTION

TS19605CA20H is a three-channel Linear LED driver with analog and PWM dimming control. This device targets at automotive lighting applications. It provides high-side drivers for LED current configured with the maximum current up to 150mA per channel. By cascade external PNP transistor can reach up to 400mA per channel.

TS19605CA20H operates with a wide input range of 4.5V to 70V and low quiescent current in standby mode. It is designed with various protection functions such as under voltage lockout (UVLO), LED-String open load voltage protection (OLP) and short circuit protection (SCP), $I_{SET}$ pin open/short protection and over-temperature protection (OTP). Diagnostic features are provided to meet automotive requirements.

## APPLICATION

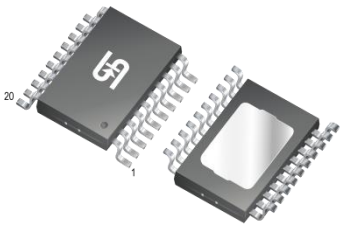
- Automotive LED Lighting:
  - Daytime Running Lamp (DRL) / Interior light
  - Stop or Tail / Position / Fog / Turn Light
- Industrial LED Applications
- General RGB or White LED Drivers

## FEATURES

- AEC-Q100 qualified with the following results:
  - Device temperature grade 1: -40°C to 125°C
  - Device HBM ESD classification level H1C
  - Device CDM ESD classification level C6
- Wide input voltage range: 4.5V to 70V
- Max. output current: 150mA per channel
  - Adjustable by external resistor
  - Accuracy: ±4% per channel when $I_{OX}$ @ 200mA
  - Accuracy: ±6% per device when $I_{OX}$ @ 200mA
  - Up to 400mA per channel @ $V_{DROPOUT}$≤1V
- Dimming function of PWM and Analog
- $V_{REF}$ pin for outside cascade structure to share the power dissipation with full loading
- Diagnostic functionalities (LED-string Open/Short, $I_{SET}$ pin Open/Short, over temperature, supply voltage)
- LED-String voltage feedback per channel for Single-LED Short Detection (SSD)
- Separate fault pin for Single-LED Short Failure
- RoHS Compliant
- Halogen-Free according to IEC 61249-2-21

Pb-Free RoHS COMPLIANT HALOGEN FREE

**TSSOP-20EP**

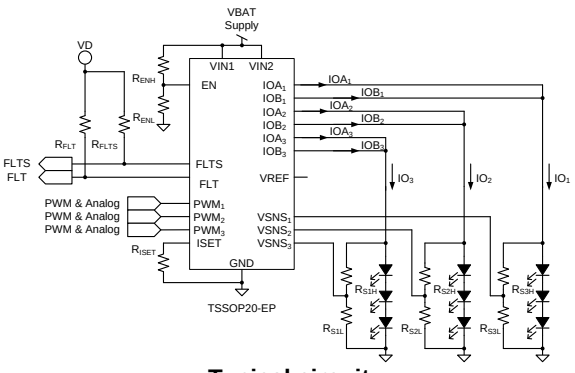



**Pin Definition:**

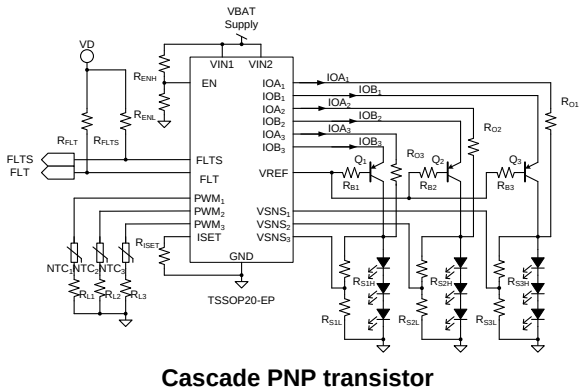
| | | | |
|---|---|---|---|
| 1. $VIN_1$ | 6. $PWM_2$ | 11. FLTS | 16. $IOA_2$ |
| 2. EN | 7. $PWM_3$ | 12. FLT | 17. $IOB_1$ |
| 3. GND | 8. $VSNS_1$ | 13. $IOB_3$ | 18. $IOA_1$ |
| 4. ISET | 9. $VSNS_2$ | 14. $IOA_3$ | 19. $VIN_2$ |
| 5. $PWM_1$ | 10. $VSNS_3$ | 15. $IOB_2$ | 20. VREF |

**Notes:** MSL 3 (Moisture Sensitivity Level) per J-STD-020

## TYPICAL APPLICATION CIRCUIT




**Typical circuit**




**Cascade PNP transistor**

| **ABSOLUTE MAXIMUM RATINGS** ($T_A$ = 25°C unless otherwise specified) (Note 1) | | | |
|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **LIMIT** | **UNIT** |
| Power input voltage - Battery power supply | $V_{VIN1}/V_{VIN2}$ | -0.3 to 75 | V |
| EN input voltage | $V_{EN}$ | -0.3 to 75 | V |
| Current channel output voltage | $V_{IOAX}/V_{IOBX}$ | -0.3 to 75 | V |
| $V_{REF}$ bias voltage | $V_{REF}$ | $V_{VIN2}$-2 | V |
| FLT/FLT_S signal voltage | $V_{FLT}$, $V_{FLTS}$ | -0.3 to 22 | V |
| ISET input voltage | $V_{ISET}$ | -0.3 to 5.5 | V |
| PWM/Analog signal input voltage | $V_{PWMX}$ | -0.3 to 5.5 | V |
| Current channel sense input voltage | $V_{VSNSX}$ | -0.3 to 5.5 | V |
| Junction Temperature Range | $T_J$ | -40 to +150 | °C |
| Storage Temperature Range | $T_{STG}$ | -65 to +150 | °C |
| ESD Rating (Human Body Mode) | HBM | ±2 | kV |
| ESD Rating (Charged Device Mode) | CDM | ±1 | kV |

| **THERMAL PERFORMANCE** (Note 2) | | | |
|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **LIMIT** | **UNIT** |
| Thermal Resistance Junction to Ambient | $R_{\theta JA}$ | 145 | °C/W |
| Thermal Resistance Junction to Ambient (Note 2-1) | $R_{\theta JA}$ | 45 | °C/W |
| Thermal Resistance Junction to Case | $R_{\theta JC}$ | 48 | °C/W |
| Thermal Resistance Junction to Case (Note 2-1) | $R_{\theta JC}$ | 15 | °C/W |

| **RECOMMENDED OPERATING CONDITION** ($T_A$ = 25°C unless otherwise specified) (Note 3) | | | |
|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **LIMIT** | **UNIT** |
| Power input voltage - Battery power supply | $V_{VIN1}/V_{VIN2}$ | 5 to 70 | V |
| EN input voltage | $V_{EN}$ | 0 to 70 | V |
| Current channel output voltage | $V_{IOAX}/V_{IOBX}$ | 0 to 70 | V |
| $V_{REF}$ bias voltage | $V_{VREF}$ | $V_{VIN2}$-2 | V |
| FLT/FLT_S signal voltage | $V_{FLT}$, $V_{FLTS}$ | 0 to 20 | V |
| ISET output voltage | $V_{ISET}$ | 0 to 5 | V |
| PWM/Analog signal input voltage | $V_{PWMX}$ | 0 to 5 | V |
| Current channel sense input voltage | $V_{VSNSX}$ | 0 to 5 | V |
| Storage Temperature Range | $T_{STG}$ | -55 to +150 | °C |
| Operating Junction Temperature Range | $T_J$ | -40 to +150 | °C |
| Operating Ambient Temperature Range | $T_{OPA}$ | -40 to +125 | °C |

| **ELECTRICAL SPECIFICATIONS** ($V_{IN}$= 14V, $T_J$ = -40°C to 150°C unless otherwise specified) | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **CONDITION** | **MIN** | **TYP** | **MAX** | **UNIT** |
| **Supply Voltage** | | | | | | |
| $V_{IN}$ Turn-on Threshold | $V_{VIN\_ON}$ | $V_{EN}$ = 5V | 4.2 | 4.8 | 5.4 | V |
| $V_{IN}$ Hysteresis | $V_{VIN\_HYS}$ | $V_{EN}$ = 5V | 0.26 | 0.33 | 0.4 | V |
| EN Turn-on Threshold | $V_{EN\_ON}$ | | 1.3 | 1.65 | 2 | V |
| Quiescent Current | $I_Q$ | $V_{EN}$ = 5; $V_{IN}$ = 4.2V | 10 | 12.5 | 26 | μA |
| Shutdown Current | $I_{SD}$ | $V_{EN}$ = 0; $V_{IN}$ = 14V | 40 | -- | 80 | μA |
| Operating Supply Current | $I_{CC}$ | Not including $IO_X$ & $I_{SET}$<br>$R_{ISET}$ =1.2kΩ; $VIO_X$=10V | 0.5 | -- | 2 | mA |
| Shutdown Current in Fault mode | $I_{Fault}$ | | 0.55 | -- | 1.3 | mA |
| **Regulator** (Note 4, 5) | | | | | | |
| Output Current Range | $IOA_X/IOB_X$ | $VIOA_X$ & $VIOB_X$ = $V_{VIN2}$-1 | 4 | -- | 400 | mA |
| Channel Accuracy | $\Delta I_{O(channel)}$ | $R_{ISET}$ = 1.2kΩ | -4 | -- | +4 | % |
| Device Accuracy | $\Delta I_{O(device)}$ | $R_{ISET}$ = 1.2kΩ | -6 | -- | +6 | % |
| Ratio of $IO_2$ to Setting Current | $K_{I\ (CH2)}$ | $R_{ISET}$ = 1.2kΩ | -- | 180 | -- | -- |
| IO Setting Reference Voltage | $V_{ISET}$ | $R_{ISET}$ = 1.2kΩ | 1.1 | 1.3 | 1.5 | V |
| $V_{IN}$-Base Reference Voltage | $V_{REF}$ | $I_{VREF}$ = 0mA; | 2.07 | -- | 2.6 | V |
| Driver capability of $V_{REF}$ | $\Delta V_{REF}$ | $I_{VREF}$ = ±20mA | -5 | -- | 5 | % |
| **Fault Flag (FLT & FLTS)** | | | | | | |
| Logic Input High Threshold | $V_{IH\_FLT(S)}$ | | 2 | -- | -- | V |
| Logic Input Low Threshold | $V_{IL\_FLT(S)}$ | | -- | -- | 0.7 | V |
| Logic Output High threshold | $V_{OH\_FLT(S)}$ | 1μA Source Current | 2 | -- | -- | V |
| Logic Output Low Threshold | $V_{OL\_FLT(S)}$ | 500μA Sink Current | -- | -- | 0.7 | V |
| Strong Pull-up Current | $I_{PU}$ | $V_{FLT(S)}$ = 3V | 500 | 750 | 1000 | μA |
| Strong Pull-down Current | $I_{PD}$ | $V_{FLT(S)}$ = 2V | 4 | 8 | 16 | μA |
| **Comparator ($VSNS_X$)** | | | | | | |
| Comparator Reference Voltage | $VSNS_{X\_REF}$ | $IO_X$ = 10mA; $VIO_X$ = 6V<br>$V_{VIN}$ > 9V | 1 | 1.2 | 1.4 | V |
| $VSNS_X$ Hysteresis | $VSNS_{X\_HYS}$ | | -- | 130 | -- | mV |
| Signal Short Detection Enable | $VIN_{SSEN}$ | $IO_X$ = 10mA; $VIO_X$ = 6V<br>$VSNS_X$ < 1V | 7.9 | 9 | 10.1 | V |
| VIN for Short Circuit Hysteresis | $VIN_{SSEN\_HYS}$ | | -- | 1 | -- | V |
| **Protection** | | | | | | |
| Open Load Detection Voltage | $V_{OLVX}$ | $V_{OLV}$ = $V_{IN}$ - $VIO_X$ | 155 | 315 | 465 | mV |
| Open Load Detection Hysteresis | $V_{OLX\_HYS}$ | $V_{OLV}$ = $V_{IN}$ - $VIO_X$ | -- | 140 | -- | mV |
| Short Detection Voltage | $V_{SCPX}$ | $IO_X$ =10mA | 0.85 | 0.95 | 1.05 | V |
| Short-detection deglitch | $T_{DG}$ | $I_{FLT}$=10mA | 1 | 2 | 3 | ms |
| | | During PWM; count the number of ms continuous cycles when $VIO_X$ < $V_{SCPX}$ | 7 | -- | 8 | ms |
| $I_{SET}$ Open Detection | $R_{ISET\_OPEN}$ | VFLT pull low | -- | -- | 200 | kΩ |

| ELECTRICAL SPECIFICATIONS ($V_{IN}$= 14V, $T_J$ = -40°C to 150°C unless otherwise specified) | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **CONDITION** | **MIN** | **TYP** | **MAX** | **UNIT** |
| $I_{SET}$ Short Detection | $R_{ISET\_SHORT}$ | VFLT pull low | 400 | -- | -- | Ω |
| **Dimming** | | | | | | |
| PWM Dimming High Threshold Voltage | $V_{OH\_PWMX}$ | | 2.5 | -- | -- | V |
| PWM Dimming Low Threshold Voltage | $V_{OL\_PWMX}$ | | -- | -- | 0.7 | V |
| Analog Dimming Threshold Voltage of 100% Current Level | $V_{MAX\_PWMX}$ | | -- | 2.4 | 2.48 | V |
| Analog Dimming Threshold Voltage of 1% Current Level | $V_{MIN\_PWMX}$ | | 0.72 | 0.8 | -- | V |
| $PWM_X$ Source Current | $I_{PWMX}$ | $V_{PWMX}$ = 2.5V | 250 | 300 | 350 | μA |
| **Thermal Section** (Note 6, 7) | | | | | | |
| Thermal Shutdown | TSD | | -- | 165 | -- | °C |
| Temperature Hysteresis | $T_{HYS}$ | | -- | 15 | -- | °C |

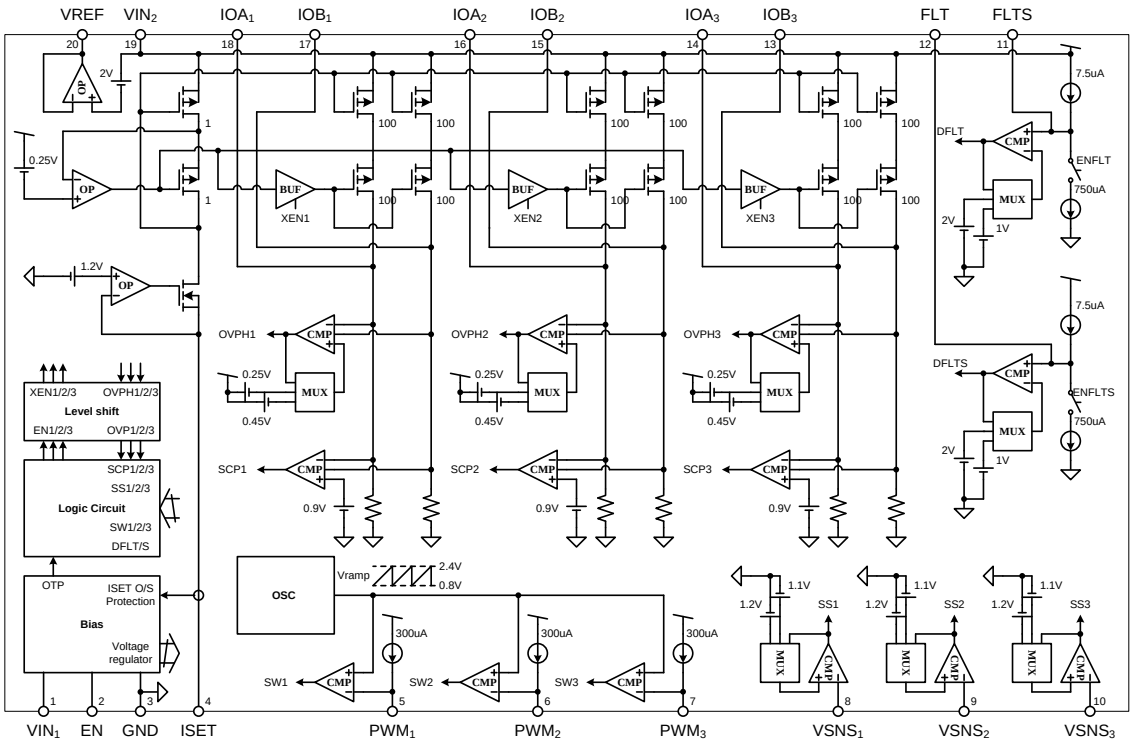
**Note:**

1. Stresses listed as the above “Absolute Maximum Ratings” may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
2. Thermal resistance is specified with the component mounted on a test board in free air with low effective thermal conductivity at $T_A$=25°C.
   2-1: Mounted on aluminum 4oz PCB
3. The device is not guaranteed to function outside its operating conditions.
4. Channel accuracy: $I_{(IOUTx)}$ - $I_{(avg)}$ / $I_{(avg)}$
   4-1: $I_{(AVG)}$ = [$I_{(IOUT1)}$ + $I_{(IOUT2)}$ + $I_{(IOUT3)}$] / 3
5. Device accuracy: $I_{(IOUTx)}$ - $I_{(setting)}$ / $I_{(setting)}$
   5-1: $I_{(setting)}$ is the target current set by $R_{ref}$.
6. Guaranteed by design.
7. Auto Recovery type.

## ORDERING INFORMATION

| ORDERING CODE | PACKAGE | PACKING |
|---|---|---|
| TS19605CA20H RLG | TSSOP-20EP | 2,500pcs / 13” Reel |

## FUNCTION BLOCK




## PIN DESCRIPTION

| PIN NO. | NAME | FUNCTION |
|---|---|---|
| 1 | $V_{IN1}$ | Battery power input voltage for bias circuit |
| 2 | EN | Enable and shut down pin |
| 3 | GND | Ground return for all internal circuitry |
| 4 | $I_{SET}$ | Connect external resistor to GND to set output current of each channel |
| 5 | $PWM_1$ | PWM/Analog dimming voltage input of Channel 1 |
| 6 | $PWM_2$ | PWM/Analog dimming voltage input of Channel 2 |
| 7 | $PWM_3$ | PWM/Analog dimming voltage input of Channel 3 |
| 8 | $VSNS_1$ | LED string voltage sense input 1 |
| 9 | $VSNS_2$ | LED string voltage sense input 2 |
| 10 | $VSNS_3$ | LED string voltage sense input 3 |
| 11 | FLTS | Single LED short fault terminal |
| 12 | FLT | Fault terminal |
| 13 | $IOB_3$ | Current output terminal 3 of B channel |
| 14 | $IOA_3$ | Current output terminal 3 of A channel |
| 15 | $IOB_2$ | Current output terminal 2 of B channel |
| 16 | $IOA_2$ | Current output terminal 2 of A channel |
| 17 | $IOB_1$ | Current output terminal 1 of B channel |
| 18 | $IOA_1$ | Current output terminal 1 of A channel |
| 19 | $V_{IN2}$ | Battery power input voltage for driver circuit |
| 20 | $V_{REF}$ | $V_{IN}$-Base reference voltage |
| - | EP | Exposed Pad. Connect EP to a large-area ground plane for effective power dissipation. Do not use as the IC ground connection |

## TYPICAL PERFORMANCE CURVES

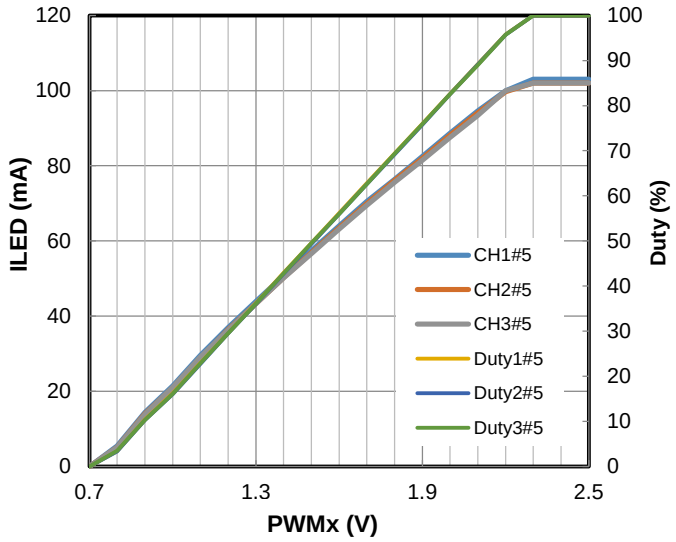



Figure 1. $I_{LED}$ vs. Analog Dimming

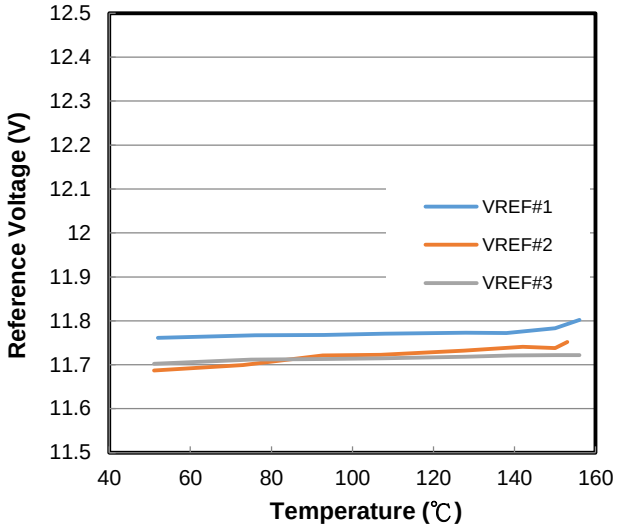



Figure 2. $V_{REF}$ vs. Temperature

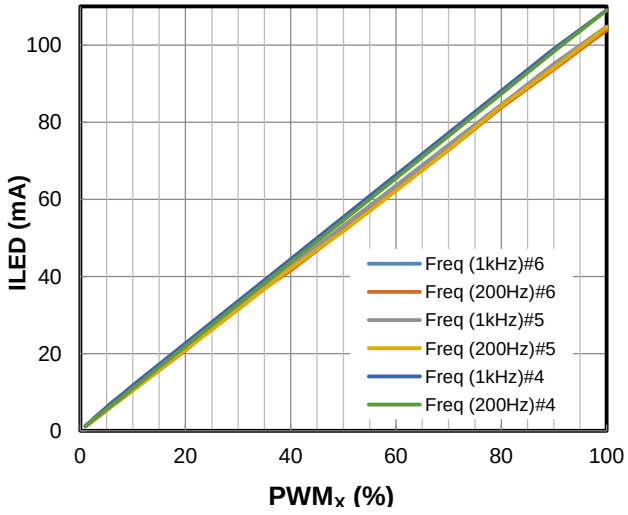



Figure 3. $I_{LED}$ vs. PWM Dimming

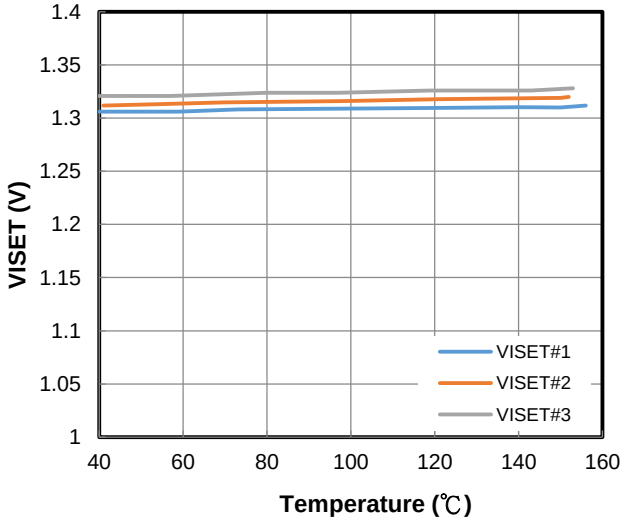



Figure 4. $V_{ISET}$ vs. Temperature

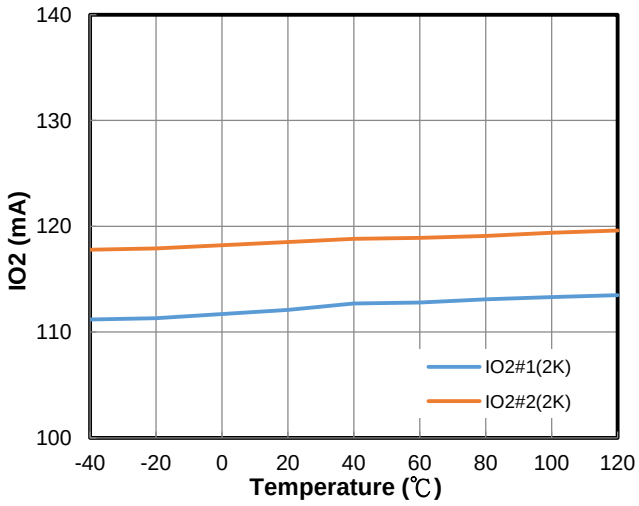



Figure 5. IO2 vs. Temperature

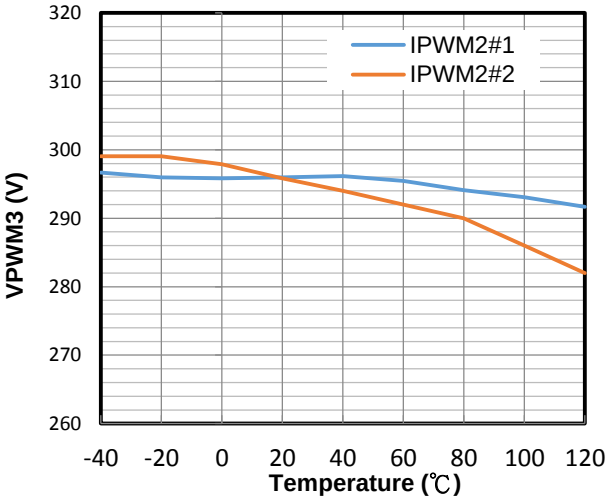



Figure 6. IPWMX vs. Temperature

## APPLICATION INFORMATION

TS19605CA20H is a 3 channel Linear LED driver with PWM and Analog dimming. It designs with constant source current of PWMX pin for linear current decrease by NTC resistor or difference each current level by resistor. The device has wide input operation voltage from 4.5 to 70V and provide three high side drivers for LED current configured. the driver current can up to 400mA per channel by cascade external PNP transistor. The device also provides $V_{IN}$-base reference voltage $V_{REF}$ for cascade structure of PNP base current to share the power dissipation or use shunt resistor to share power dissipation.

TS19605CA20H monitor the fault conditions from the thermal, $I_{OX}$, $V_{SNSX}$ and $I_{SET}$ pin to report its status on the FLT and FLTS terminal. The Fault condition Include thermal shutdown, LED load open/short, single LED short and $I_{SET}$ pin open/short. Two separate fault terminals allow maximum flexibility of fault-mode reporting to the MCU in case of an error.

### Pin Definitions

#### $VIN_X$ Pin

Power supply input for the TS19605 during normal operation. $V_{IN1}$ major in IC bias current, $V_{IN2}$ is for output driver current. The device will start up when $V_{VIN}$ reaches 4.8V (typical) and will shut down when $V_{VIN}$ voltage is below 4.5V (typical). For the signal LED short detection function. $V_{VIN}$ must be reaches 9V (typical) and will shut down when $V_{IN}$ voltage is below 8V (typical).

#### EN Pin

The EN pin can sense $V_{IN}$ information by voltage divider resister setting or directly connect to $V_{IN}$ pin. The device will enable on the device when $V_{EN}$ over 2V.

#### GND Pin

GND is the reference node of internal circuit.

#### ISET Pin

The output current could be linearly adjusted through variable resister connected between $I_{SET}$ and GND pin.

#### $PWM_X$ Pin

A PWM and Analog dimming function is applied in TS19605CA20H. The Analog dimming range is an analog voltage from 0.8V to 2.4V and the PWM dimming function is the same pin of analog dimming. The current regulation is decided by duty cycle of external PWM signal. Built-in 300μA source current to decided analog dimming voltage by resistor or NTC application.

#### $VSNS_X$

The $VSNS_X$ pin can sense LED string information by voltage divider resister to define the single LED short condition.

## APPLICATION INFORMATION (CONTINUE)

### FLT/FLTS Pin

There are two separate fault terminals (FLT/FLTS) allow maximum flexibility of fault-mode reporting to the MCU. And they are I/O terminals for many control mechanisms as below table.

### Fault Table

| Fault Type | Fault Select | Condition | FAULT (V) | FAULTS (V) | $IO_X$ (V) | $IO_X$ (V) | $IO_X$ (V) | Failure Removed | Fault Clear |
|---|---|---|---|---|---|---|---|---|---|
| SHORT | FAULT & FAULTS Floating | $IO_X$ Short GND<br>V(VIN) > 5V; V(IOUTX) < 0.9V | Pulled Low | Pulled Low | OFF | OFF | OFF | Latch | Restart (EN) |
| | | $IO_X$ Single LED short<br>V(VIN) > 9V; V(VSNSX) < 1.2V | Pulled High | Hiccup | ON | ON | ON | Latch | Restart (EN) |
| | FAULT & FAULTS Externally Pulled High | IOX Short GND<br>V(VIN) > 5V; V(IOUTX) < 0.9V | Pulled High | Pulled Low | OFF | ON | ON | Latch | Restart (EN) |
| | | $IO_X$ Single LED short<br>V(VIN) > 9V; V(VSNSX) < 1.2V | Pulled High | Pulled High | ON | ON | ON | Latch | Restart (EN) |
| OPEN | FAULT Floating | Iout1 OPEN; V(VIN) > 5V<br>V(VIN)-V(IOX)<br><300mV | Pulled Low | Pulled High | OFF | OFF | OFF | Auto recover | Auto recover |
| | FAULT Externally Pulled High | Iout1 OPEN; V(VIN) > 5V<br>V(VIN)-V(IOX)<br>< 300mV | Pulled High | Pulled High | OFF | ON | ON | Auto recover | Auto recover |
| Thermal shutdown | FAULT Floating | V(VIN) > 5V<br>Temperature >165°C | Pulled Low | Pulled Low | OFF | OFF | OFF | Temperature < 155°C | Auto recover |
| ISET Pin open or short | FAULT Floating | RREF > 200kΩ<br>V(VIN) > 5V | Pulled Low | Pulled Low | OFF | OFF | OFF | Latch | Restart (EN) |
| | FAULT Floating | RREF < 400Ω<br>V(VIN) > 5V | Pulled Low | Pulled Low | OFF | OFF | OFF | Latch | Restart (EN) |

### $IO_X$ Pin

This is the current output pin to driver LED load. The output current can be expressed as below.

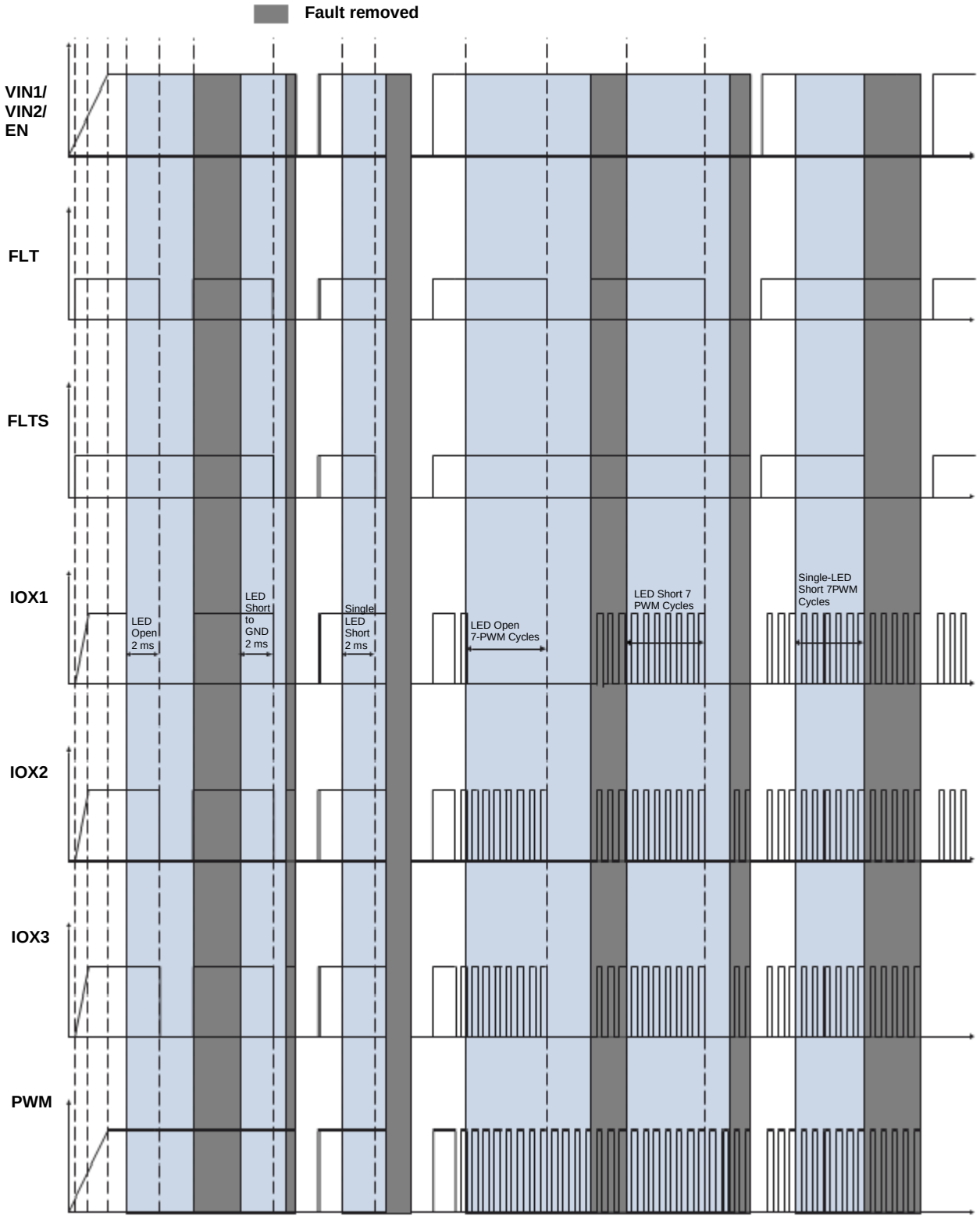
$$IOA_X = IOB_X = 0.5 \times K_I \times \frac{V_{ISET}}{R_{ISET}} = 0.5 \times IO_X$$

Where:

- $K_I$ is the ratio of current factor
- $V_{ISET}$ is the internal reference voltage (1.2V)
- $R_{ISET}$ is the sensing resistor connected between ISET pin and the GND

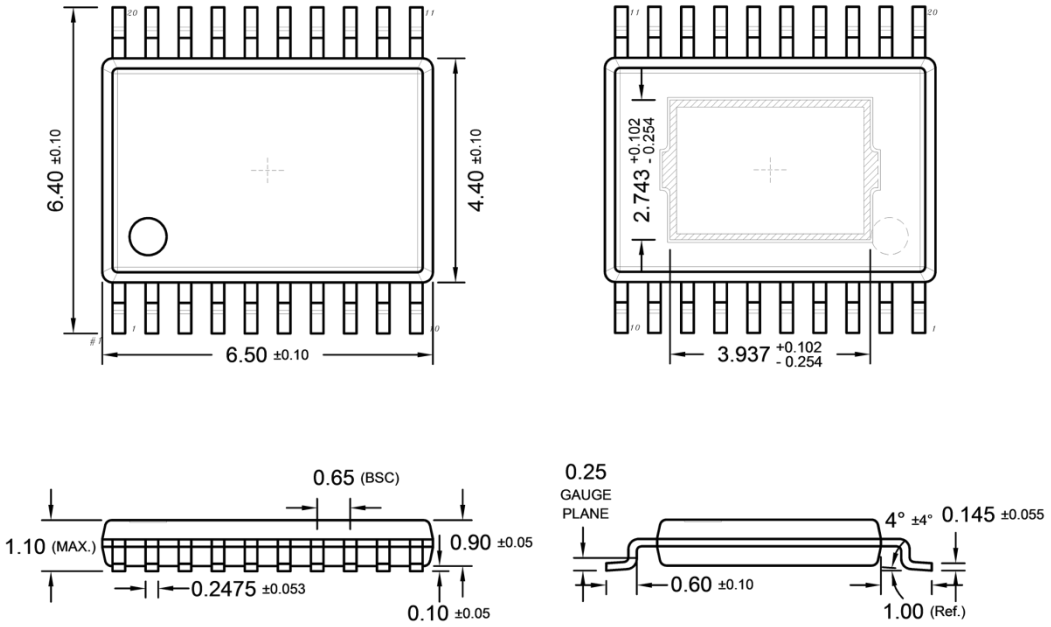
## APPLICATION INFORMATION (CONTINUE)

**Detail Timing Diagram**

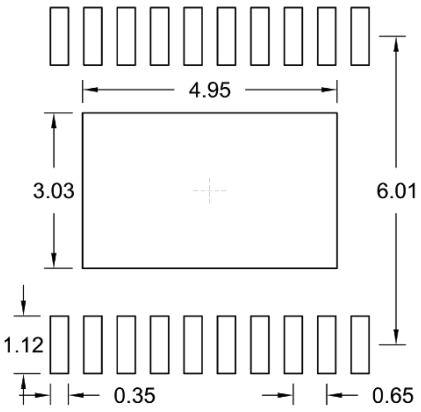


## PACKAGE OUTLINE DIMENSIONS (Unit: Millimeters)

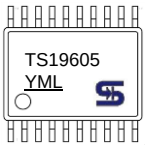
**TSSOP-20EP**




## SUGGESTED PAD LAYOUT (Unit: Millimeters)




## MARKING DIAGRAM




**Y** = Year Code

**M** = Month Code for Halogen Free Product

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **O** | =Jan | **P** | =Feb | **Q** | =Mar | **R** | =Apr |
| **S** | =May | **T** | =Jun | **U** | =Jul | **V** | =Aug |
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**L** = Lot Code (1~9, A~Z)

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